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ORIGINAL RESEARCH

INJURY IDENTIFICATION: THE EFFICACY OF THE FUNCTIONAL MOVEMENT SCREEN™ IN FEMALE AND MALE RUGBY UNION PLAYERS

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ABSTRACT

Background: Rugby union is a collision sport which is associated with a high injury rate and therefore the development of effective injury prevention strategies is required.

Purpose: This study aimed to determine whether the Functional Movement Screen™ (FMS™) components can predict injury in female and male rugby union players and whether differences exist in the FMS™ scores of injured and non-injured players.

Study Design: Prospective cohort study.

Methods: Sixty-four female university rugby union players (age: 20.39 ± 1.91 years) and 55 male university rugby union players (age: 21.05 ± 1.35 years) completed the FMS™ which assesses seven functional movements on a scale of 0 to 3 and provides a total or composite score out of 21. Players were subsequently monitored for injury during the season and injury rates calculated.

Results: The training injury rates for females were 5.80 injuries/1000 hours and males 5.34 injuries/1000 hours while the match injury rates for females was 55.56 injuries/1000 hours and males 46.30 injuries/1000 hours. FMS™ composite score demonstrated a significant difference between injured females and non-injured males ($p = 0.01$) and a combined sample comparison of injured and non-injured subjects was significant ($p = 0.01$). FMS™ composite score was not a good predictor of injury however as FMS™ individual components predicted 37.4% of the variance in total days injured in females. ROC curve analysis revealed an injury cut off score of 11.5 for females and males and provided a sensitivity and specificity of 0.90 and 0.86 and 0.88 and 1.00 respectively. The combined sample FMS™ composite score of *'multiple injuries'* participants demonstrated no significant difference between non-injured ($p = 0.31$) and single injury subjects ($p = 0.76$).

Conclusion: Injury rates between female rugby and male rugby were similar with match injury rates higher in females. The FMS™ can be used to identify those players with the potential to develop injury and the FMS™ injury cut off point was 11.5 for both female rugby and male rugby players. Individual components of the FMS™ are a better predictor of injury than FMS™ composite score.

Key words: Female, Functional Movement Screen™, injury, male, rugby union

Levels of Evidence: 2b.

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Conflict of interest
The authors report no conflicts of interest.

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INTRODUCTION

Rugby union is a collision sport which involves physical contact in scrums, rucks, mauls, line outs and tackling and repeated short duration high intensity workloads[1] which contribute to one of the highest reported sporting injury rates.[2] Within collegiate rugby, match and training injury rates of 99.5 injuries and 5.1 injuries per 1000 hours have been recorded respectively.[3]

The Functional Movement Screen (FMS™)[4,5] has been used to predict injury across a variety of sports including female collegiate athletes[6] and football[7] based on the suggestion that strength, movement flexibility and stability are required for optimal performance.[8] The FMS™ is a screening tool that consists of seven movements that are graded to identify deviation from normal movement patterns via visual analysis by the tester. The movements are deep squat (DS), hurdle step (HS), in-line lunge (ILL), shoulder mobility (SM), active straight leg raise (ASLR), trunk stability push up (PU) and rotary stability (RS) which are scored from 0 to 3 on each movement providing a maximum score of 21.[4,5] The FMS™ has good inter-rater reliability (Intraclass Correlation Coefficients (ICC) 0.89)[9] and scientific evidence exists for the use of the FMS™ as a predictor of injury risk.[8]

Injury risk is multifactorial[10,11] and attempts have been made to create injury risk algorithms for collegiate athletes using field expedient tests (Lower Quarter Y-Balance Test and FMS™) and historical factors (previous injury history and current medical restriction) to categorize injury risk.[12] It was concluded that these field expedient tests in combination with demographic information may help categorize injury risk however the definition of injury used meant that these findings were most applicable to musculoskeletal injuries of non-contact mechanism.[12] In US Army Rangers a combination of predictors were investigated and musculoskeletal injury history, pain provocation on FMS™ clearing tests, movement tests and lower scores on physical performance measures were associated with increased risk of injury.[13] The summation of risk factors produced a sensitive model (one or less factor) and a specific (three or more factors model) for identifying injury risk.[13]

The implementation of injury prevention strategies may potentially reduce the high injury rate reported in rugby. Within female rugby there are limited injury studies at university level[14,15] and neither utilized movement screening. To the best of the authors' knowledge no studies exist that have investigated FMS™ as a predictive tool of injury in female university rugby players (FR) and male university rugby players (MR). The primary aim of the study was to determine whether FMS™ composite score and FMS™ individual components can predict injury occurrence in FR and MR. The secondary aim was to report injury demographics in FR and MR and whether differences exist in the FMS™ composite scores of injured and non-injured players. The tertiary aim was to consider the FMS™ composite score of subjects who suffered 'multiple injuries' in comparison to non-injured and single injury subjects. The final aim was to consider the role of contusion injuries.

METHODS

Subjects

One hundred and nineteen subjects volunteered to participate in this study (64 FR: age: 20.39 $\pm$ 1.91 years, height: 166.5 $\pm$ 10.55 cm, mass: 73.98 $\pm$ 21.03 kg, 55 MR: age: 21.05 $\pm$ 1.35 years, height: 181 $\pm$ 6.26 cm, mass: 86.60 $\pm$ 14.01 kg). Subjects were recruited at the relevant team training session if they were 18 years of age or older; currently a member of the university rugby union team and attending training and playing matches on a weekly basis. Subjects were excluded from the study if they had suffered an injury in the previous 30 days[6] which prevented them participating in or completing a training session or match. Subjects completed a medical screening questionnaire prior to participating in the study and those who had heart disease and/or were pregnant were excluded from the study. Subjects who scored 0 on any FMS™ movements were excluded from the study. Participation was voluntary and all subjects completed informed consent forms and were provided with an information sheet prior to commencing the study and a debrief sheet following participation. The University Research Ethics Committee provided ethical approval prior to commencing the study in accordance with the Helsinki declaration.

Procedures

Prior to testing, the subjects height (cm) was measured using a stadiometer (Leicester Height Measure, Child Growth Foundation, Leicester, UK) and body mass (kg) was recorded using digital scales (Salter 9028, Kent, UK) and the subjects date of birth was recorded. Subjects were asked to eat their normal pre-training meal, avoid performance enhancing energy drinks, supplements and strenuous exercise in the 48 hours before testing to reduce fatigue effects and all testing was conducted at 17.00 hours. The researcher was a Musculoskeletal Physiotherapist with 16 years of experience and an MSc in Sports Medicine who was trained in using the FMS™ via attendance at a Functional Movement Screening course.

FMS™

Subjects performed the seven movements of the FMS™[4,5] which were demonstrated by the researcher who also provided FMS™ images[4,5] to support correct movement patterns. Verbal instruction was provided to the participants in accordance with guidelines previously reported by Cook et al.[16] Subjects performed each movement three times with a five-second rest between each movement and a one minute rest between each component of the FMS™.[17] The highest score on the three trials were recorded by the lead researcher and subjects returned to their initial standing position between trials. Clearing tests were performed for SM, PU and RS[4,5] to determine if any subjects had pain that would make performance of these tests unsafe. Performance was assessed on a scale of 0 to 3 based on the following criteria: 0 = Subjects experienced pain during movement, 1 = Subject failed to complete the functional movement, 2 = Subject performed using compensatory movement, and 3 = Subject performed the test to perfection.[4,5] For bilateral movements the lowest score in that FMS™ component was used for analysis and calculation of composite score.[4,5]. No subjects scored 0 on any FMS™ movement and therefore all subjects were pain free. The Intra-rater reliability (ICC $_{3,1}$) of FMS™ composite score[18] was assessed by the lead researcher who measured the FMS™ scores of 20 subjects (10 male, 10 female) on two separate occasions 24 hours apart to allow calculation of test-retest reliability. ICC's were calculated to assess intra-rater reliability and FMS™ composite score had an ICC of 0.99 (95% Confidence Intervals (CI) 0.97 – 0.99) which demonstrated excellent intra-rater reliability.

Injury definition and playing exposure recording

Injury was categorized using a time loss definition of injury that defined injury as an event that prevented the player from taking full part in rugby training or matches.[19] Absence was recorded as Total Days Injured (TDI) using Injury Recording Cards[19] and recorded prospectively. Players who were unable to participate in training or matches following an injury were assessed by the researcher and had their injury classified via differential diagnosis as either sprain, strain, contusion, fracture, dislocation, overuse injury or other.[20] The following information was recorded: (1) Injury location. (2) Classification of injury type. (3) Mechanism of injury: (a) Contact injuries resulting from physical contact with a player or equipment (e.g. rugby post) (b) Non-contact injuries. (4) Injury severity: Was graded as slight (0-1 days), minimal (2-3 days), mild (4-7 days), moderate (8-28 days) and severe (greater than 28 days).[19] Players were defined as having recovered from injury once they had been assessed by the researcher and allowed to return to full contact training which included all the physical demands of rugby (e.g. scrums, rucks, mauls, line outs, tackling) or when they started a match. This individual assessment of injury status involved fitness tests of physical demands that would occur in rugby (e.g. sprinting, cutting, tackling, jumping) and appropriate musculoskeletal assessment via joint and muscle testing. Absence due to illness was not recorded to ensure only injury status was investigated. Reinjury was classified as injury of the same type occurring at the same location[20] and the term *'multiple injuries'* was used for those subjects who suffered more than one injury during the study and did not include reinjuries. Training and match exposure (minutes) was recorded by the researcher using a playing and training time attendance register and results are reported as (mean $\pm$ SD). Injury rates calculated as injury/1000 hours training and match exposure.

Statistical analysis

All analysis was performed using the combined sample and further analysed for both males and females and separately. For regression analysis a Durbin-Watson test was used to assess independence of observations and a scatterplot was used to assess linearity between FMS™ variables and TDI. Case wise diagnostics were used to check for outliers. The assumption of homoscedasticity was checked by inspection of a plot of the unstandardized values against predicted values.[21] Normal probability-probability (P-P) plots were used to assess normal distribution and ensure that the variance in residuals were constant. Cohen's *d* was used to assess effect size[22] for all regression analysis. Linear regression, multiple linear regression and stepwise multiple hierarchical linear regression analysis was used to quantify the effect of FMS™ composite and FMS™ individual components scores as a predictor of TDI. Linear regression analysis was used to quantify the Pearson correlation coefficient (r) between FMS™ composite score and TDI. Multiple linear regression was subsequently used to correlate TDI with each of the independent FMS™ components. This approach quantifies TDI as a function of the discrete elements. Stepwise multiple hierarchical linear regression was used to establish a hierarchical ordering for those FMS™ components which most influence TDI. This technique used the seven FMS™ components with the highest r entered in pairs into the model commencing with the element with the highest r value. All assumptions were met for all regression analysis. To consider the role of contusion injuries and the possibility they may potentially occur due to chance, all forms of regression analysis were repeated with contusion injuries removed from analysis.

Quantile-quantile (Q-Q) plots were observed and the groups were observed to be normally distributed. For one-way Anova analysis of FMS™ composite scores in injured FR, non-injured FR, injured MR and non-injured MR there was homogeneity of variances as assessed by Levene's test for equality of variances ($p = 0.40$). A post-hoc Tukey test was used to analyse differences between groups and a partial eta squared squared (η^2) calculation provided effect size. An independent t-test was used to analyse FMS™ composite score in injured and non-injured subjects. Q-Q plots were observed and the groups were observed to be normally distributed. There was homogeneity of variances as assessed by Levene's test for equality of variances for all three comparisons (combined, $p = 0.76$, FR, $p = 0.61$, MR, $p = 0.18$). This analysis of injured and non-injured subjects included all injuries recorded and a separate analysis was performed with contusion injuries removed and homogeneity of variance existed for all three comparisons (combined, $p = 0.96$, FR, $p = 0.39$, MR, $p = 0.29$). An independent t-test was used to assess FMS™ composite score between *'multiple injuries'* subjects and those who had suffered no injury or one injury. Due to the low numbers of subjects classified as *'multiple injuries'*, meaningful statistical analysis was only possible between combined sample *'multiple injuries'* and non-injured subjects and combined sample *'multiple injuries'* and single injury subjects. Homogeneity of variance existed for both comparisons with values of ($p = 0.63$ and $p = 0.57$) respectively. A separate analysis was performed with contusion injuries removed and homogeneity of variance existed for *'multiple injuries'* subjects and non-injured subjects ($p = 0.71$) and *'multiple injuries'* and single injury subjects ($p = 0.62$). Receiver operator characteristic (ROC) curves were produced to assess the predictive ability of the FMS™ composite scores and FMS™ components between injured and non-injured subjects and to determine the cut-off score for sensitivity and specificity as a predictor of injury.[23] A separate ROC analysis was performed with contusion injuries removed. Descriptive injury data was provided for the mechanism of injury and injury rates calculated as injuries/1000 hours for training, match and combined sample values. Statistical analysis was performed using SPSS version 23 software (IBM Inc.) and statistically significant differences were described at the $p < 0.05$ level.

RESULTS

Regression analysis

Table 1 reports linear regression analysis of FMS™ composite score as a predictor of TDI for all injuries. FMS™ composite score was a significant predictor for combined sample ($p = 0.04$) and FR ($p = 0.03$). The best FMS™ component predictor was FR LIL (r^2 .12, Durbin Watson 2.23, $p = 0.01$, $F = 8.23$). FMS™ composite score had a small Cohen's *d* effect size for combined sample (.19), MR (.20) and FR (.27)[22] in relation to TDI.

Analysis with contusions removed revealed no differences in statistical outcome. FMS™ composite

Table 1. *FMS™ composite score (Mean/SD) as a predictor of Total Days Injured (Mean/SD).*

Group	r^2	F- value	p- value
Total Sample	.04	4.47	0.04*
MFMS 14.71 (2.36)			
MTDI 11.08 (16.24)			
FR	.07	4.71	0.03*
MFMS 14.44 (2.47)			
MTDI 8.06 (12.50)			
MR	.04	2.25	0.14
MFMS 15.02 (2.20)			
MTDI 14.60 (19.26)			

Abbreviations: MFMS; Mean Functional Movement Score; MTDI: Mean Total Days Injured, FR; Female Rugby Players, MR; Male Rugby Players
** Significant at p <0.05*

score was a significant predictor for combined sample (r^2 .04, Durbin Watson 2.192, p = 0.04, F = 4.29, Cohen's *d* .20). FMS™ composite score was a significant predictor of FR TDI (R^2 .07, Durbin Watson 2.085, p = 0.04, F = 4.06, Cohen's *d* .26). FMS™ composite score was not a significant predictor for MR TDI (r^2 .04, Durbin Watson 2.386, p = 0.14, F = 2.21, Cohen's *d* .20). The best FMS™ component predictor remained FR LIL (r^2 .13, Durbin Watson 2.05, p = 0.01, F = 7.87, Cohen's *d* .36).

Multiple linear regression analysis of all FMS™ components included in the regression model together as a predictor of TDI revealed a significant difference for FR (r^2 .37, Durbin Watson 2.21, p = 0.01, F = 2.54). Combined sample analysis produced the following values: (r^2 .149, Durbin Watson 2.37, p = 0.12, F = 1.55) and MR analysis demonstrated the following values: (r^2 .18, Durbin Watson 2.51, p = 0.69, F = 0.75). FMS™ components had a medium Cohen's *d* effect size for combined sample (.39) and MR (.42) and a large effect size for FR (.61).[23] Multiple linear regression analysis of all FMS™ components with contusion injuries removed resulted in significant findings remaining for FR TDI (r^2 .39, Durbin Watson 2.23, p = 0.03, F = 2.26, Cohen's *d* .62). Combined sample analysis was non-significant for TDI (r^2 .14, Durbin Watson 2.39, p = 0.22, F = 1.33, Cohen's *d* .38). MR TDI demonstrated non-significant findings (r^2 .24, Durbin Watson 2.34, p = 0.53, F = 0.93, Cohen's *d* .49).

Table 2 reports a stepwise multiple hierarchical linear regression of FMS™ components as a predictor of TDI and the hierarchical ordering of discrete FMS™ components, quantifying *r* at each step. The ordering of individual elements therefore highlights the test elements with the greatest individual predictive power for FMS™ composite score. The Cohen's *d* effects size for FMS™ components were combined sample (.28), FR (.43) and MR (.34). Analysis with contusions removed did not alter significant findings for combined sample analysis and TDI (p = 0.02, F = 3.97), FR and TDI (p = 0.01, F = 4.83), MR and TDI (p = 0.19 , F = 1.83).

Injury analysis

Table 3 reports independent t-test analysis of the FMS™ composite scores of injured and non-injured subjects. All assumptions were confirmed. There was a significant difference between combined sample non-injured and injured (p = 0.01). Mean FMS™ composite scores were highest in MR non-injured (15.53 ± 1.89) and lowest in FR injured (13.76 ± 2.70). Following the removal of contusion injuries the analysis was repeated and all assumptions were confirmed. A significant difference remained between combined sample non-injured and injured (p = 0.03, 95% CI 0.111-1.95)

There was a statistically significant difference between male and female groups (injured and non-injured) for FMS™ composite score (p = 0.02). There was a significant difference in FMS™ composite score between MR non-injured and FR injured subjects (p = 0.01). Partial eta squared (η^2) was 0.07 which is considered a medium effect size.[23] All other comparisons were non-significant. Analysis was repeated with contusion injuries removed and the significant difference in FMS™ composite score between male and female groups (injured and non-injured) (p = 0.03) and between MR non-injured and FR injured subjects (p = 0.01) remained. All other comparisons were non-significant.

There was no significant difference in FMS™ composite score between combined sample *'multiple injuries'* subjects and non-injured subjects (p = 0.31) or

Table 2. *Stepwise multiple hierarchical linear regression of FMS™ components as a predictor of total days injured.*

Group	r^2	Pearson r	DW	F- value	p- value
CS RSM LIL	.06	RSM -.19	2.35	3.94	0.02*
RSM LIL LSLR LHS	.08	LIL -.16			
RSM LIL LSLR LHS RHS LRS	.08	LSLR -.15			
		LHS -.15			
		RHS -.11			
		LRS -.09			
FR LIL LRS	.14	LIL -.34	2.29	4.81	0.01*
LIL LRS RIL RHS	.16	LRS -.25			
LIL LRS RIL RHS RSM LHS	.19	RIL -.24			
		RHS -.24			
		RSM-.22			
		LHS -.22			
MR LHS RHS	.07	LHS -.26	2.47	1.82	0.17
LHS RHS PU RSM	.11	RHS -.19			
LHS RHS PU RSM LIL LSLR	.12	PU -.19			
		RSM -.14			
		LIL -.09			
		LSLR -.07			

CS; Combined Sample, FR; Female Rugby, MR; Male Rugby, RSM; Right Shoulder Mobility; LIL; Left In-line Lunge, LSLR; Left Straight Leg Raise; LHS; Left Hurdle Step; RHS; Right Hurdle Step; LRS; Left Rotary Stability; RIL; Right In-line Lunge, PU; Push Up; DW: Durbin Watson

* Significant at $p < 0.05$

Table 3. *FMS™ composite scores of injured and non-injured participants.*

Group	FMS™ (Mean/SD)	p value (95% CI)
CSNI	15.12 (2.31)	0.01* (0.21-1.81)
CSI	14.11 (2.42)	
MRNI	15.53 (1.89)	0.06 (-0.45- 2.11)
MRI	14.40 (2.44)	
FRNI	14.53 (2.44)	0.22 (-0.46-1.99)
FRI	13.76 (2.70)	

CSNI; Combined Sample Not Injured, CSI; Combined Sample Injured, MRNI; Rugby Male Rugby Not Injured, MRI; Male Rugby Injured, FRNI; Female Rugby Not Injured, FRI; Female Rugby Injured SD; Standard Deviation, CI; Confidence Intervals, MD; Mean Difference

* Significant at $p < 0.05$

between combined sample *'multiple injuries'* subjects and single injury subjects (p = 0.76). Analysis was repeated with contusion injuries removed and the non-significant findings for FMS™ composite score between combined sample *'multiple injuries'* subjects and non-injured subjects (p = 0.41) and between combined sample *'multiple injuries'* subjects and single injury subjects (p = 0.86) remained.

ROC curve analysis

ROC curve analysis of FMS™ composite score demonstrated an area under the curve for differentiating between injured and non-injured players of combined: (0.39, standard error 0.05, asymptomatic 0.04, 95% CI 0.29-0.49); FR: (0.41, standard error 0.07, asymptomatic 0.23, 95% CI 0.27-0.55); MR: (0.38, standard error 0.08, asymptomatic 0.11, 95% CI

0.23-0.52). Figure 1 presents ROC curve combined samples analysis of FMS™ composite score, DS and PU. Figure 2 reports presents analysis of SM, SLR, and RS. Figure 3 presents ROC combined samples analysis of ILL and HS.

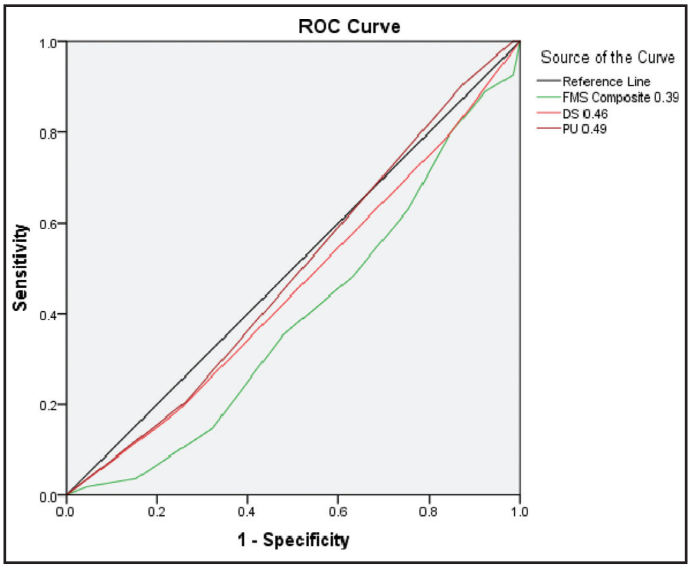

Figure 1. *ROC curve pooled analysis of FMS composite score, deep squat, trunk stability push up.*
FMS: Functional Movement Screen; DS: Deep Squat; PU: Push Up

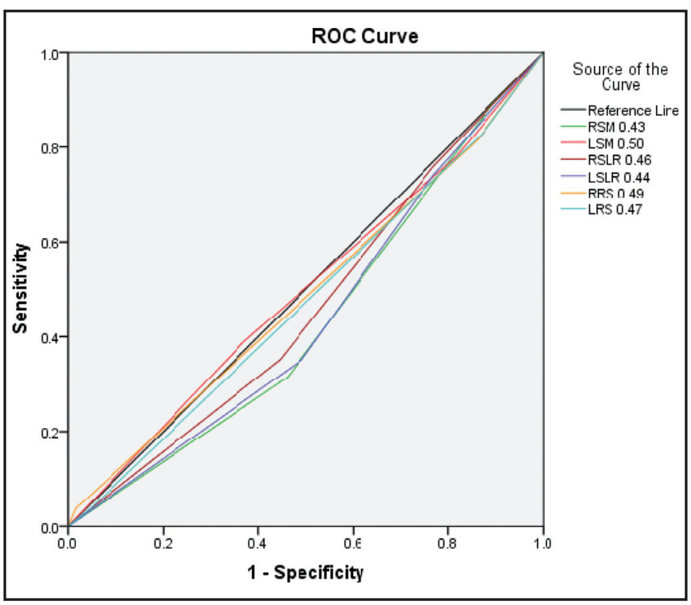

Figure 2. *ROC curve pooled analysis of shoulder mobility, straight leg raise and rotary stability*
RSM: Right Shoulder Mobility; LSM: Left Shoulder Mobility; RSLR: Right Straight Leg Raise; LSLR: Left Straight Leg Raise; RRS: Right Rotatory Stability; LRS: Left Rotatory Stability

For FMS™ individual components the area under the curve of FR PU (0.58, standard error 0.08, asymptomatic 0.12, 95% CI 0.23-0.52); MR right RS (0.52, standard error 0.08, asymptomatic 0.85, 95% CI 0.36-0.67) were the best FMS™ components at differentiating between injured and non-injured subjects. Figure 4 reports ROC analysis of FR PU. Table 4 reports ROC curve sensitivity and specificity using

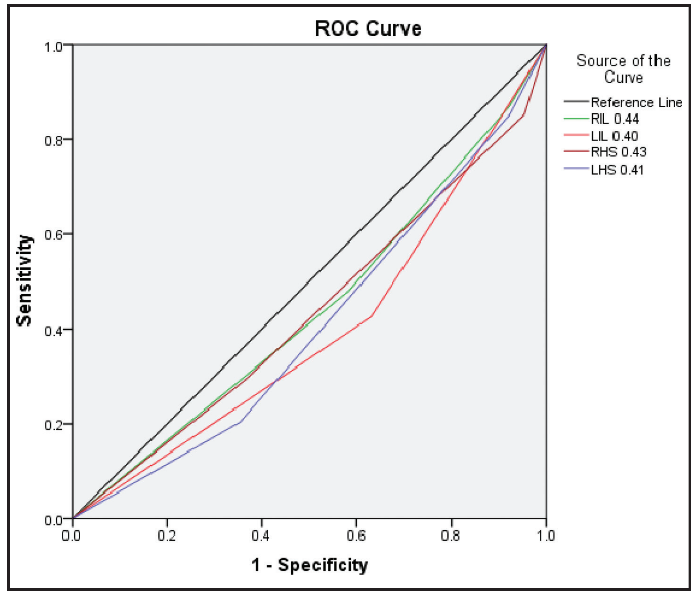

Figure 3. *ROC curve pooled analysis in-line lunge and hurdle step*
RIL: Right In-line Lunge; LIL: Left In-line Lunge; RHS: Right Hurdle Step; LHS: Left Hurdle Step

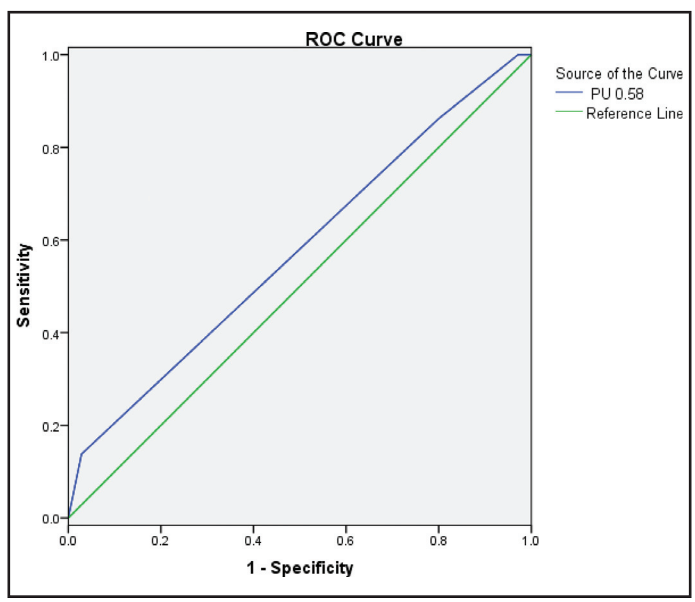

Figure 4. *ROC curve analysis of female rugby push up*
PU: Push Up

Table 4. *ROC curve analysis of sensitivity and specificity values of FMS™ composite score.*

Group Variable	Positive if ≥ to	Sensitivity	Specificity
CS	11.5	0.89	0.92
FMS™ composite score	12.5	0.80	0.85
	13.5	0.63	0.75
	14.5	0.48	0.63
	11.5	0.90	0.86
FR	12.5	0.79	0.77
FMS™ composite score	13.5	0.59	0.69
	14.5	0.41	0.57
	11.5	0.88	1.00
	12.5	0.80	0.93
MR	13.5	0.68	0.83
FMS™ composite score	14.5	0.56	0.70

CS; Combined Sample, FMS; Functional Movement Score, FR; Female Rugby Players, MR; Male Rugby Players

FMS™ composite score values from 11.5 to 14.5 as a predictor of injury cut off. The following cut of points were identified for FMS™ composite score: Combined sample 11.5; FR 11.5, MR 11.5. ROC analysis with contusions removed did not alter FMS™ composite findings to any great extent with the following values obtained: combined: (0.38, standard error 0.05, asymptomatic 0.04, 95% CI 0.27-0.49); FR: (0.38, standard error 0.08, asymptomatic 0.15 (95% CI 0.24-0.53); MR: (0.38, standard error 0.08, asymptomatic 0.13, 95% CI 0.22-0.53). FR PU and MR right RS remained the best FMS™ components at differentiating between injured and non-injured subjects with no change in values.

Match and training exposure

Combined sample match and training time was 230341 mins (1935.63 ± 982.19), combined sample match time was 67961 mins (571.1008 ± 367.96), combined sample training time was 162380 mins (1364.54 ± 714.50). FR combined sample match and training time was 101601 mins (1563.09 ± 822.30), match time was 29161 mins (448.63 ± 369.29) and training time was 72440 mins (1114.47 ± 557.21). MR combined sample match and training time was 128740 mins (2384.07 ± 977.87), match time was 38800 mins (718.52 ± 310.20) and training time was 89940 mins (1665.56 ± 769.84).

Injury rate

Table 5 reports injury rates and TDI in FR and MR. Seventy-two injuries (FR 34 (47%), MR 38 (53%)) occurred in 28 FR and 25 MR. For FR two players suffered two injuries and two players suffered three injuries. For MR 9 players suffered two injuries and two players suffered three injuries. For FR 7 (21%) injuries occurred in training and 27 (79%) in a match and for MR 8 (21%) injuries occurred in training and 30 (79%) in a match. One RM suffered a reinjury. All injuries were from a contact or non-contact mechanism.

Injury severity

For FR the following injury severity was recorded: 28 days+ (1, 1(100%) contact), 8-28 days (23, 16 (70%) contact), 4-7 days (6, 3 (50%) contact), 2-3 days (4, 2 (50%) contact). For MR the following injury severity was recorded 28 days+ (7, 7 (100%) contact), 8-28

Table 5. *Injury rates, total days injured (TDI) and contact and non-contact injuries.*

Group	TI & MI /1000 hrs	TI/1000 hrs	MI/1000 hrs	Contact injuries (n)	Non-contact injuries (n)	TDI (Mean/SD)
CS	18.75	5.54	50.32	48 (9T, 39M)	24 (6T,18M)	1319 (11.08 ± 16.24)
FR	20.08	5.80	55.56	22 (4T, 18M)	12 (3T,9M)	516 (8.06 ± 12.50)
MR	17.71	5.34	46.30	26 (5T, 21M)	12 (3T, 9M)	803 (14.60 ± 19.26)

CS; Combined sample, FR; Female Rugby Players, MR; Male Rugby Players, TI; Training Injury, MI; Match Injury HRS; Hours, n; number, SD; Standard Deviation, T; Training, M; Match

days (27, 16 (59%) contact), 4-7 days (3, 2 (67%) contact), 2-3 days (0), Up to one day (1, 1 (100%) contact).

Injury type

Injury type is reported in Table 6. The most common injury in FR was latissimus dorsi muscle strain (5, 15%) and in MR was ankle ligament sprain (6, 16%).

Table 6. *Injury type.*

Injury type	FR	MR
Ankle ligament sprain	4 (12%)	6 (16%)
Ankle contusion	3 (9%)	2 (5%)
Knee ligament sprain	3 (9%)	5 (13%)
Knee contusion	2 (6%)	2 (5%)
Rotator cuff strain	4 (12%)	3 (8%)
Shoulder contusion	1 (3%)	0 (0%)
Shoulder dislocation	0 (0%)	2 (5%)
Hip contusion	2 (6%)	2 (5%)
Adductor strain	0 (0%)	4 (11%)
Latissimus dorsi muscle strain	5 (15%)	2 (5%)
Hamstring strain	1 (3%)	2 (5%)
Quadriceps strain	1 (3%)	2 (5%)
Gastrocnemius strain	0 (0%)	1 (3%)
Wrist sprain	0 (0%)	2 (5%)
Finger contusion	1 (3%)	1 (3%)
Dislocated finger	1 (3%)	0 (0%)
Rib contusion	1 (3%)	0 (0%)
Concussion	3 (9%)	2 (5%)

Abbreviations: FR; Female Rugby Players, MR; Male Rugby Players

DISCUSSION

The primary aim of the study was to determine whether FMS™ composite scores and FMS™ components can predict injury in FR and MR. There was a statistically significant ability of the FMS™ composite score to serve as a predictor of TDI for combined sample and FR results however the r^2 values (Table 1) suggest that FMS™ composite score is a weak predictor of TDI. FMS™ composite score had a small Cohen's *d* effect size for combined sample and MR and was approaching a medium effect size for FR in relation to TDI. These findings of the limited predictive value of FMS™ composite score may be due in part to the FMS™ test not being a unitary construct. Multiple linear regression analysis with all FMS™ individual components demonstrated that FMS™ individual components were a statistically significant predictor of 37.4% of the variation in TDI in FR which highlights contribution of these individual components in comparison to the FMS™ composite score. FMS™ components had a medium effect size for combined sample and MR and a large effect size for FR. Therefore, clinicians involved in injury prevention should consider that potential gender differences may exist when designing an injury prevention program.

Stepwise multiple hierarchical linear regression (Table 2) demonstrated significant findings for FR and demonstrates that LIL and LRS alone were able to predict 13.6% of variance in TDI and the addition of four more components increased this predictive ability to 19.1%. Future FR screening could consider these two components if time constraints existed. RSM, LIL, LHS and RHS featured in the top six predictors of TDI across combined, FR and MR analysis and therefore future studies may wish to investigate the impact of these components. However caution must be observed as r^2 values indicated that none of the individual components were a strong predictor. The effect size for FMS™ components was small for combined sample and medium for FR and MR.

The secondary aim was to report injury demographics and to determine whether differences exist in the FMS™ scores of injured and non-injured subjects. FR training injury rates of 5.80 injuries/1000 hours and MR training injury rate of 5.34 injuries/1000 hours were similar to the 5.5 injuries/1000 hours in both males and females reported in American collegiate rugby union.[14] The similarity between FR and MR total injury rates is in contrast to the reported the overall incidence rate which was 30% higher for men than women in intercollegiate club rugby players[15] however comparison is limited by the different method utilized for calculating injury rate with this study[15] utilizing an injury incidence rate per 10000 athlete exposures. FR and MR match injury rates of 55.56 injuries/1000 hours and 46.30/1000 hours were higher than those previously reported of 17.1 injuries/1000 hours in FR and 16.9 injuries/1000 hours in MR.[14] However this study[14] failed to record training duration exposure and made calculations based on practice hours exposure which limits comparison. The match injury rate in MR is similar to the match injury rate of 47 injuries/1000 hours.[24] In amateur male rugby players (20-24 years) a match injury rate of 13.95/1000 hours has been reported[25] while female match injury rates of 20.5/1000 hours have been reported in participants in elite senior women[26] which are much lower than the current study. Such variations may be explained by varying injury recording methodologies and that higher skilled players may be more adept at avoiding contact injuries. In agreement with previous findings[14] most injuries were contact injuries (67%) highlighting the physical demands of rugby. The similarity between injury rates in male and females in the current study may suggest that at university level, differences observed in the professional game in terms of the contact nature of the game are reduced.

Combined sample analysis of mean FMS™ composite score of injured and non-injured subjects (Table 3) revealed a significant difference ($p = 0.01$), however separate gender analysis revealed no significant difference for FR ($p = 0.22$) and MR ($p = 0.06$). The mean FMS™ composite scores of injured subjects was lower than non-injured subjects in both FR 13.76 ($\pm$ 2.70) v 14.53 ($\pm$ 2.44) and MR 14.40 ($\pm$ 2.44) v 15.53 ($\pm$ 1.89). Mean FR FMS™ injured scores were below the increased risk of injury cut off point of ≤ 14 reported in female collegiate athletes.[6] In male American football players a combination of at least one movement asymmetry and a score < 14 had an injury specificity of 0.87.[27] In the current study the limited number of severe injuries ($n = 8$) prevented meaningful statistical analysis however previous findings in male rugby players who suffered a severe injury reported significantly lower FMS™ composite score and differences existed between contact injured and non-injured groups in DS, ILL and SLR.[28] The current finding of only one reinjury is important as the presence of a large number of subjects with reinjuries may bias the sample due to the presence of *'injury prone'* individuals, however this was not a problem within the study. The current study did not measure previous injury which has been identified as a risk factor for injury [12,13] as self-reported injury is prone to bias. However the tertiary aim was to report differences between *'multiple injuries'* subjects and non-injured and single injury subjects. Combined sample analysis of FMS™ composite score of *'multiple injuries'* subjects revealed no significant difference between these subjects and non-injured subjects ($p = 0.31$) and single injury subjects ($p = 0.76$). This finding suggests that the FMS™ composite score may not be a factor in the development of multiple injuries however analysis is limited by the small sample of subjects who had multiple injuries ($n = 15$, contusions not removed) which also prevented separate gender analysis. Regression analysis regarding contributors to *'multiple injuries'* subjects was not advocated due to the small sample size.

ROC curve analysis demonstrated that the FR, PU (.58), MR, and right RS (.52) were the best FMS™ components at differentiating between injured and non-injured subjects however these values cannot be considered diagnostic as 0.5 can be considered a chance level.[23] ROC curve analysis allowed calculation of a score that provided sensitivity and specificity for the identification of injured participants. Analysis indicated that for the combined sample group a score of 11.5 provided a sensitivity of .89 and specificity of .92 while for FR a score 11.5 provided a sensitivity of .90 and a specificity of .86 and for MR a score of 11.5 provided a sensitivity of .88 and a specificity of 1.00. These values may aid injury management and training load monitoring by allowing coaching staff to implement intervention programs to improve movement competency and/or adjust workload when a specific FMS™ value is achieved which might be suggestive of potential injury. In MR, the SLR test detected 96% of severe injuries and that the odds of a severe injury were 9.4 times greater in those with an SLR ≤ 2.[28] However specificity was low (0.29) and many players who were below this cut off did not suffer severe injuries and a combined sample ILL and SLR were reported as most valuable for predicting injury.[28]

The results of the current study indicate that FMS™ composite scores in non-injured rugby players are significantly greater than injured rugby players. A significant difference existed for FMS™ composite score between FR injured and MR non-injured players. The cut off for injury diagnosis with similar measures of sensitivity and specificity is 11.5 for FR and MR. These findings have value for the practitioner as they demonstrate the potential benefits of using quantifiable objective measures such as the FMS™ to monitor potential injury development. Players who are identified as being potentially at risk of injury may benefit from repeated FMS™ screening to monitor FMS™ scores. Intervention programs that aim to alter movement patterns can be implemented and the subsequent effect on FMS™ score monitored. It is of paramount importance that practitioners identify movement inefficiency that may produce abnormal movement patterns and injury. Minimal differences for match and training injury rates between FR and MR may highlight the increasing physical nature of FR. In this study seven out of eight severe injuries occurred in MR and therefore differences in injury severity require a further prospective cohort study with a larger sample size, and with more FR players. The predictive capacity of FMS™ composite score to predict TDI was limited and the use of discrete components had greater predictive capacity particularly within FR were only two components (LIL, LRS) had a predictive capacity of 13.6%, however this should be considered a low predictive capability and may highlight that FMS injury cut off scores are more useful. With regard to potential injury development the importance of the DS and SLR has been highlighted in competitive distance runners[29] and the ILL in athletes.[30] Future studies may wish to consider performing the FMS™ post injury when participants return to play to allow comparison of any potential alterations in FMS™ scores.

With regard to the final aim of the study, statistical analysis was performed with contusion injuries removed based on the possibility that some contusion injuries may be due to chance and therefore the identification of whether these injuries are likely to occur might be difficult via the FMS™. The removal of contusion injuries made no change to the significant findings that were observed when all injuries were included. Tackling is associated with a high injury rate[31,32,33] and rugby players should be taught proper tackling technique[34] and high levels of agility are required to evade tackles.[34] The ability to evade technique could potentially be enhanced by training using FMS™ movements. The ILL has been highlighted as the primary predictor of T-test agility performance in female and male rugby union players[35] and it is possible that progressing from FMS™ movements into rugby specific movements such as cutting and offloading the ball may be beneficial and aid agility and tackle avoidance. The relationship between performance and injury requires further investigation. One focus could be whether specific functional movements of the FMS™ such as the ILL, DS, PU which form movements of some key rugby movements such offloading, retrieving the ball from the ground and returning to standing following a tackle have greater importance when attempting to enhance performance and rehabilitate a player following injury. Future studies could consider whether the high prevalence of contact injures are due to poor technique in tackling or due to other contact related movements.

Some limitations exist in the current study, as the correlation coefficients and statistical power of regression analysis is influenced by the number of participant and variables. This study used three different types of regression analyses to improve the robustness of the methodology. The prospective nature of this study provided a comprehensive form of injury surveillance and prevented recall bias. Previous research has highlighted the multifactorial nature of injury[10,11] and that injury etiology occurs in a dynamic recursive fashion[11] as risk factors can change during sport exposure. The authors acknowledge that injury is multifactorial and therefore although the use of the FMS™ is advocated in the identification of injury in rugby it may potentially be used in the context of an injury prevention program that considers factors such as previous injury and how multiple injury risks may interact. The FMS™ is one potential tool that may identify movement patterns that potentially predispose an athlete to injury.

CONCLUSION

The findings of the current study indicate that the FMS™ can be used to identify those players with the potential to develop injury and the injury cut off point of 11.5 in FR and MR may aid identification of these individuals. Mean FMS™ composite scores are lower in both injured FR and MR in comparison to non-injured players and the individual components of the FMS™ are a more valuable predictor of injury than FMS™ composite score. Injury rates between FR and MR are similar with FR match injury rates higher than MR which maybe reflective of the increasing physical nature of female rugby. The FMS™ composite score of *'multiple injuries'* players was not statistically different to non-injured and single injury players and this may provide a focus for future research.

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